IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)
e-ISSN: 2319-2380, p-ISSN: 2319-2372. Volume 17, Issue 3 Ser. 1 (March. 2024), PP 55-58
www.iosrjournals.org

Utilization Of Nanoparticles In The Agriculture Industry For Sustainable Development With Specific Reference To Carbon And Silica-Based Nanoparticles

P.S.S Deepak*, Sangeeta Sankhyayani Achanta**
**Agricultural Graduate, Lovely Professional University*
***Research Scholar, Dept. Of Environmental Sciences, Acharya Nagarjuna University*

Abstract
The world is facing great challenges in meeting rising demands for basic commodities (e.g., food, water and energy), finished goods (e.g., cell phones, cars and airplanes) and services (e.g., shelter, healthcare and employment) while reducing and minimizing the impact of human activities on Earth's global environment and climate. Nanotechnology has emerged as a versatile platform that could provide efficient, cost-effective and environmentally acceptable solutions to the global sustainability challenges facing society.
In agricultural sector in particular, nanotechnology plays an important role in crop production, food processing and packaging, food security and water purification, environmental remediation, crop improvement, and plant protection. Agricultural productivity can be improved through nanomaterial-induced genetically improved animals and plants, site-specific drug and gene delivery of molecules at cellular/molecular levels in animals and plants, and nano-array-based genetic modification in animals and plants in stress conditions.
Keywords :*Agricultural productivity, Environmental remediation, Crop improvement, Nanotechnology*

Date of Submission: 20-03-2024 Date of Acceptance: 30-03-2024

I. Introduction:

Nanoparticles are extremely fine particles whose size ranges between 1-100 nanometers pose different properties, shapes, and sizes. Due to these unique aspects, they are suitable for a variety of commercial processes in the field of diagnostics, pharmaceuticals, agriculture, and environmental applications (Khan et al., 2017). The use of nanoparticles in Agriculture can provide a major advantage in increasing the effectiveness of agricultural inputs. This offers an opportunity for the development of sustainable systems in the agriculture industry as traditional agriculture depends on the use of heavy doses of chemical fertilizers that often leaks into the water bodies. Nanoparticles can be used in a variety of agricultural products like plant growth stimulators, pesticides, fertilizers, and herbicides that are encapsulated in nanocarriers. This use of nanoparticles enhances crop yields, eliminates pathogens and weeds from crops and provides an opportunity to eliminate insets in a cost and energy-efficient manner. The waste generation is also reduced due to the utilization of nanoparticles (Singh et al., 2021).

Agricultural productivity can be improved through nanomaterial-induced genetically improved animals and plants, site-specific drug and gene delivery of molecules at cellular/molecular levels in animals and plants, and nano-array-based genetic modification in animals and plants in stress conditions. Nanotechnology has the potential of precise delivery of agrochemicals for improving disease resistance, plant growth, and nutrient use. Nano encapsulated products show the ability of more effective and site-specific use of pesticides, insecticides, and herbicides in an eco-friendly and greener way. It is successfully used in postharvest for maintaining freshness, quality, and shelf life of stored product and preventing disease occurrences in a fairly safer way.

Silicon-based nanoparticles have distinctive benefits compared to silicon bulk material. Due to their unique physiological properties, nanoparticles of silicon may reach plants and affect their processes of metabolism. Additionally, silica nanoparticle's mesoporous structure renders them appealing options for use as nanocarriers for various compounds that could prove useful in farming. Silicon-based nanoparticles can transform the industries like plant biotechnology and agriculture. These nanoparticles are seen as an environmentally friendly substitute for the current chemical fertilizers that is harmful to the environment (Rastogi et al., 2019). Carbon-based nanoparticles have the potential to play a critical part in the future of agriculture as they can enhance crop yield and promote much-needed sustainability in conventional agriculture practices (Zhu et al., 2022) and promote sustainable agriculture.

Due to the increase in the global population, there is a need for reform in the agriculture sector so that the nutrition requirements of the growing population can be satisfied. More than 30% of crops in conventional agriculture gets destroyed due to pest, microorganism, substandard quality of soil, and scarce nutrition. Therefore, there is a need to think about solutions to the above-mentioned problems and nanotechnology has the potential to provide the solution to these issues. It has the potential to transform agriculture practices and ensure sufficient food supply to the growing population. The use of nanoparticles in conventional agrichemicals can improve the health of crops and enhance soil structure (Mittal et al., 2020). There are various advanced methodologies that could benefit from the use of nanotechnology.

In the context of agriculture, it facilitates the sequencing of deoxyribonucleic acid (DNA), and nanosensors, and can act as a catalyst. Carbon-based nanoparticles pose unique physiochemical properties that can be used for benefit in the field of agriculture. The study revealed that carbon-based nanoparticles have the ability to improve plant development, germination of seeds, and the extension of roots. There are cost-related concerns about the use of nanotechnology in the field of agriculture and due to this, only large companies are able to use nanotechnology (Shojaei et al., 2019). In agriculture, nanotechnology can be used to produce slow-release nano fertilizers for fertilizer use by plants; Nano fertilizers also called smart fertilizer are either nanomaterials (NMs) which supply single or multiple nutrients to plants improving development and yield of crops or those which compliments better performance of conventional synthetic fertilizers, without directly supplying nutrients to crops. A nano fertilizer is a product in nanometer level that supply nutrients to specific target sites and can improve nutrient use efficiency (NUE) and diminish environmental degradation.

The usage of nanoparticles in seed before sowing is comparatively safe as several metabolic, physiological, and morphological changes occur before the plant biomass or seed production takes place. The high initial vigor, foliage growth, and good germination in thickly sown crop help in suppressing the weeds and enhancing the biomass. Some promoting and promising results have been found regarding enhancement of germination and yield. The way through which the nanomaterials are absorbed into the plants and their subsequent movement within plant tissues and organs is very important while formulating the nanoproduct. The formulation varies depending on the absorption of active ingredient through leaves or roots of plants. Root can easily absorb nanocides Nanomaterials are used efficiently for safe administration of pesticides, herbicides, and fertilizers at lower doses to cover big plant surfaces and thousands of plants, but if the nanomaterial is imbibed through leaves, then better efficiency will be obtained.

II. Scope Of The Study

The present study would explore the use of nanoparticles in the agriculture sector so that the agriculture practices are more sustainable and environmentally friendly. The study is industry-specific and examines the impact of nanoparticles in the context of the agriculture sector only. To facilitate this the current study would start with exploring the literature, followed by a collection of primary data from farmers, agriculture scientists, and other stakeholders in the farming industry. It is not possible to cover the perspective of all farmers and stakeholders, so the study would collect data from 100-200 farmers and agriculture scientists. The responses from these participants would be analyzed for generating insight into the use of carbon and silica-based nanoparticles for sustainable agriculture.

III. Application Of Nanoparticles

One of the most prominent emerging fields in science is nanotechnology which is based on the use of nanoparticles. These particles are classified into various categories based on their chemical composition. Nanoparticles have various applications across different fields. In medicine, it is used for biological labeling, drugs, and gene delivery, investigating protein and DNA structure, imaging, and treating diseases like cancer. Nanoparticles are being used as a chemical catalysts for carrying out chemical reactions. Nanoparticles have found application in the energy sector. Nanoparticles are being used in the production of energy by splitting electrochemical water. Nanoparticles can serve as an effective way for energy storage. For the transformation of mechanical energy into chemical energy, nanogenerators are being used (Ijaz et al., 2020). Nanoparticles can act as an effective agent for the treatment of cancer. The physical properties and design of the nanoparticles allow them to pierce the microenvironment of the tumor and deliver the drug. Nanoparticles can also be used along with traditional therapy for cancer like chemotherapy (Yang et al., 2021).

Along with medicine, nanoparticles have found application in renewable energy sources, as it used in biofuels. Nanoparticles are considered in this field as they can enhance the production of various biofuels like biogas, biodiesel, and bioethanol. The yield of these bioproducts can be enhanced by using nanoparticles. We have to consider the impact of nanoparticles on microorganisms present in biofuels and their environmental impact (Sekoai et al., 2019).

IV. Nanoparticles For The Promotion Of Sustainable Agriculture.

In order to make agriculture practices more sustainable use of new fertilizers known as "Smart Fertilizers" are being discussed. The use of urea and calcium-based nano-fertilizers for the cultivation of grapes has shown encouraging results (Gaiotti et al., 2021). Fungal infestation in crops is very common and the use of metal nanoparticles is considered a useful alternative to control the fungal infestation. The study found that the use of metal nanoparticles as antifungal agents has provided positive outcomes. The metal-based nanoparticles are a good substitute for the commonly used chemical-based fungicides. These antifungal agents are effective against different species of fungus. These nanoparticles are less pollutive compared to the traditional alternative (Cruz-Luna et al., 2021). More sustainable agriculture practices can take advantage of nanocarrier technologies for the encapsulation of agricultural chemicals and plant growth regulators. Gibberellic acid, a commonly used growth regulator that is used for the treatment of plant seeds, can be encapsulated in nanocarriers. This does not only improved plant growth but also ensured that the production of fruit is increased.

Another advantage of using nanocarriers is that they are non-toxic in nature as opposed to traditional alternatives (Pereira et al., 2019). It is increasingly important now to promote agricultural processes that have a low impact on the environment and the well-being of consumers. Not just chemicals, but nanoparticles can be used to carry natural pesticides like neem oil. This need oil is encapsulated in corn protein nanoparticles to check its toxicity to the organism that is not being targeted. This is an example of how nanoparticles can be used for the elimination of targeted organisms that cannot be done using chemical pesticides. Therefore, nanoparticles can not only improve the efficiency of the pesticide but can prevent their adverse impact on the other non-target organism in the environment (Pascoli et al., 2019).

V. Challenges Associated With The Utilization Of Nanoparticles In The Agriculture Industry.

Nanotechnology has the potential to solve the most difficult issues that presently hinder more environmentally friendly agriculture, such as enhancing controlling pest effectiveness, fighting the effects of global warming, and minimizing adverse environmental effects. However, there are many barriers that prevent the impact implication of nanoparticles in the field of agriculture, like reduced efficiency in the field compared to the laboratory, issues related to regulations and safety, and the acceptance from the customers. The study suggests that more research is required to deliver nanoparticles to plants in a more effective manner to provide results at the field level, a need for reform in regulations and there is a need for communicating the benefits of nanoparticles with the public (Hoffman et al., 2020). Agrochemicals enclosed in nanoparticles are preferable over conventional free agrochemicals. Even nanoparticles can have some negative impact on the environment. There is a need to understand the toxic impact of nanoparticles enclosed pesticides. Fungicides are often enclosed in metal-based nanoparticles to target specific system of fungus and eliminate the effect of resistance in fungi, however, the environmental impact of these metal-based nanoparticles are still now well understood. Due to the excessive use of pesticides, the number of pollinating insects is reducing and this is a big concern around the world. However, metal-based nanoparticles enclosed pesticides can be more target specific and reduce the impact of pesticides on the pollinator population (Chaud et al., 2021).

Nanotechnology is an emerging field of science and many industries are looking for taking advantage of nanoparticles for overcoming the current barriers they are facing in their area. These fields include but are not limited to agriculture, medicine, renewable energy, and chemical industries. Nanoparticles are considered an enabler for sustainable agriculture as discussed by Pascoli et al., (2019), Pereira et al., (2019), and Cruz-Luna et al., (2021). However, these studies are limited as they are concerned with the use of nanoparticles with one specific chemical for sustainable agriculture in one specific crop or plant. There is a gap in research that describes how nanoparticles are impacting and transforming the agriculture industry as a whole and making it more environmentally friendly and sustainable. As pointed out by Chaud et al. (2021), the toxicity of nanoparticle-based agrochemicals is not much explored and their impact on the environment is not very well understood. Therefore, this study would explore how the nanotechnology, especially nanoparticles is impacting the agriculture sector and how the current challenges faced by the agriculture industry concerning the utilization of nanoparticles can be overcome. The current study would also try to study nanoparticles with specific reference to carbon and silica-based nanoparticles and their role in making contemporary agriculture practices more sustainable and environmentally conscious.

VI. Current Problems In Agriculture And Solution

The environment is polluted by current farming practices, endangering consumer health, food security, and the fight against climate change. There is a need to shift from traditional agricultural practices to more sustainable agriculture practices (Adegbeye et al., 2020). Modern agriculture practices use a massive dose of chemical fertilizers and pesticides. Unsustainable agricultural practices lead to soil degradation, desertification, pollution of water, and contamination of the food supply. Hence it is increasingly important to shift to more sustainable agriculture practices at a rapid pace. It includes reducing the use of chemical fertilizers and

pesticides, using irrigation water in a more responsible manner, and cultivating crops according to the nature of the soil and climate. Novel techniques such as the use of nanoparticles can enhance sustainability in agriculture processes. The current study would examine the role of nanoparticles in sustainable agriculture practices with specific reference to carbon and silica-based nanoparticles. According to Chaud et al. (2021), there are barriers associated with the use of nanoparticles, hence the current study would examine these challenges and explore how these barriers can be overcome. The outcome of this study would help the practitioners better understand how nanoparticles can benefit the farmer and the environment as well. The present study would explore the role of nanoparticles in sustainable agriculture and the challenges associated with it.

VII. Expected Outcome Of The Study

The outcome of this study would provide insights to the farmers who are looking for ways to sustainable farming, as it would enhance their understanding of how they can utilize nanoparticles to improve their soil structure and minimize the use of chemical fertilizers and pesticides. The study would also discuss the challenges associated with nanoparticulate in the context of agriculture and how to overcome them. The study would also provide useful insights to researchers in the agricultural domain. It would provide them with knowledge on how effective use of nanoparticles can benefit the crop yield and environment. It would inspire them to further test the application of nanoparticles. Lastly, policymakers around the globe are concerned with food security and the study would likely provide them with guidance about how to reduce the use of chemical fertilizers and pesticides.

References:

[1] Adegbeye, M. J., Reddy, P. H., Obaisi, A., Elghandour, M. M., Oyebamiji, K. J., Salem, A. Z., Morakinyo-Fasipe, O., Cipriano-Salazar, M., & Camacho-Díaz, L. M. (2020). Sustainable Agriculture Options For Production, Greenhouse Gasses And Pollution Alleviation, And Nutrient Recycling In Emerging And Transitional Nations - An Overview. Journal Of Cleaner Production, 242, 118319. Https://Doi.Org/10.1016/J.Jclepro.2019.118319

[2] Gaiotti, F., Lucchetta, M., Rodegher, G., Lorenzoni, D., Teissedre, P., Longo, E., Cesco, S., Belfiore, N. P., Lovat, L., Delgado-López, J. M., Carmona, F., Guagliardi, A., Masciocchi, N., & Pii, Y. (2021). Urea-Doped Calcium Phosphate Nanoparticles As Sustainable Nitrogen Nanofertilizers For Viticulture: Implications On Yield And Quality Of Pinot Gris Grapevines. Agronomy, 11(6), 1026. Https://Doi.Org/10.3390/Agronomy11061026

[3] Hofmann, T., Lowry, G. V., Ghoshal, S., Tufenkji, N., Brambilla, D., Dutcher, J. R., ... & Wilkinson, K. J. (2020). Technology Readiness And Overcoming Barriers To Sustainably Implement Nanotechnology-Enabled Plant Agriculture. Nature Food, 1(7), 416-425.

[4] Ijaz, I., Gilani, E., Nazir, A., & Bukhari, A. (2020). Detail Review On Chemical, Physical And Green Synthesis, Classification, Characterizations And Applications Of Nanoparticles. Green Chemistry Letters And Reviews, 13(3), 223–245. Https://Doi.Org/10.1080/17518253.2020.1802517

[5] Khan, I., Saeed, K., & Khan, I. A. (2017). Nanoparticles: Properties, Applications And Toxicities. Arabian Journal Of Chemistry, 12(7), 908–931. Https://Doi.Org/10.1016/J.Arabjc.2017.05.011

[6] Mittal, D., Kaur, G., Singh, P., Yadav, K., & Ali, S. F. (2020). Nanoparticle-Based Sustainable Agriculture And Food Science: Recent Advances And Future Outlook. Frontiers In Nanotechnology, 2. Https://Doi.Org/10.3389/Fnano.2020.579954

[7] Pascoli, M., Jacques, M. T., Agarrayua, D. A., Avila, D. S., Lima, R., & Fraceto, L. F. (2019). Neem Oil Based Nanopesticide As An Environmentally-Friendly Formulation For Applications In Sustainable Agriculture: An Ecotoxicological Perspective. Science Of The Total Environment, 677, 57-67.

[8] Pandey, P., & Pandey, M. M. (2021). Research Methodology Tools And Techniques. Bridge Center.

[9] Pereira, A. D. E. S., Oliveira, H. C., & Fraceto, L. F. (2019). Polymeric Nanoparticles As An Alternative For Application Of Gibberellic Acid In Sustainable Agriculture: A Field Study. Scientific Reports, 9(1). Https://Doi.Org/10.1038/S41598-019-43494-Y

[10] Rastogi, A., Tripathi, D. K., Yadav, S., Chauhan, D. K., Zivcak, M., Ghorbanpour, M., Elsheery, N. I., & Brestic, M. (2019). Application Of Silicon Nanoparticles In Agriculture. 3 Biotech, 9(3). Https://Doi.Org/10.1007/S13205-019-1626-7

[11] Sekoai, P. T., Ouma, C. N., Du Preez, S., Modisha, P., Engelbrecht, N., Bessarabov, D., & Ghimire, A. (2019). Application Of Nanoparticles In Biofuels: An Overview. Fuel, 237, 380–397. Https://Doi.Org/10.1016/J.Fuel.2018.10.030

[12] Singh, R., Handa, R., & Manchanda, G. (2021). Nanoparticles In Sustainable Agriculture: An Emerging Opportunity. Journal Of Controlled Release, 329, 1234–1248. Https://Doi.Org/10.1016/J.Jconrel.2020.10.051

[13] Shojaei, T. R., Salleh, M. J., Tabatabaei, M., Mobli, H., Aghbashlo, M., Rashid, S. A., & Tan, T. (2019). Applications Of Nanotechnology And Carbon Nanoparticles In Agriculture. Elsevier Ebooks, 247–277. Https://Doi.Org/10.1016/B978-0-12-815757-2.00011-5

[14] Yang, M., Li, J., Gu, P., & Fan, X. (2021). The Application Of Nanoparticles In Cancer Immunotherapy: Targeting Tumor Microenvironment. Bioactive Materials, 6(7), 1973–1987. Https://Doi.Org/10.1016/J.Bioactmat.2020.12.010

[15] Zhu, L., Chen, L., Gu, J., Ma, H., & Wu, H. (2022). Carbon-Based Nanomaterials For Sustainable Agriculture: Their Application As Light Converters, Nanosensors, And Delivery Tools. Plants, 11(4), 511. Https://Doi.Org/10.3390/Plants11040511